Annual Project Summary
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Title:	Radiated Energy and State of Stress During Earthquake Rupture
Investigator:	Hiroo Kanamori
Institution:	California Institute of Technology
Address:	Seismological Laboratory 252-21 California Institute of Technology 1200 E. California Blvd. Pasadena, California 91125
Telephone:	(626) 395-6914
FAX:	(626) 564-0715
E-mail address:	hiroo@gps.caltech.edu
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Investigation

Our investigation during the period October 1, 2000 through September 20, 2001, was focused on the synthesis of the results obtained by the research supported by this grant. We made a detailed study of the energy release from the 1999 Hector Mine, California, earthquake. The result of this study will be published in Venkataraman et al. [2001] (also summarized in the previous report). In relation to this work, we analyzed high-quality data from several Japanese earthquakes including the 2000 Tottori, Japan, earthquake. This work was partially supported by a grant from the National Science Foundation and the Ministry of Education, Culture, Sports, Science and Technology, Japan. Also, for interpretation of these results, we investigated an elasto-hydrodynamic lubrication model. The result of this work has been published in Brodsky and Kanamori [2001].

Results

The results from the 1999 Hector Mine earthquake and several Japanese earthquakes including the 2000 Tottori earthquake together with the results for small earthquakes obtained by other investigators strongly suggest that the ratio of radiated energy E_R to the seismic moment M_0, E_R / M_0, for large events ($Mw > 5$) is 10 to 100 times larger than that for small earthquakes ($Mw < 2.5$). A summary of recent results is shown in Figure 1. This suggests some drastic change in fault dynamics between small and large earthquakes. One possible explanation is that large earthquakes tend to occur on well-developed mature faults, and the fracture energy can be very small. On the other hand, the fracture energy associated with small earthquakes is relatively large, which results in the small E_R / M_0 ratio.

Another interesting possibility is that, if faulting occurs within a very narrow slip zone, the effect of shear heating and fracturing tends to lubricate the fault plane, thereby increasing the radiation efficiency. In the presence of fluids, a strictly mechanical effect reduces friction independently of the thermal effect. If the fault zone is thin and rough, and if the material in the fault zone behaves as a viscous fluid, the shearing of the fault fluid produces a viscous stress which is balanced by dynamic pressure. The fluid pressure rises, which reduces friction and elastically deforms the fault planes. This elasto-hydrodynamic lubrication reduces friction for large events relative to small events.

An interesting consequence is that as the slip and slip velocity increase, the pressure increase within a narrow zone, caused by either thermal or hydrodynamic effects, becomes large enough to smooth out the irregularities on the fault surface by elastic deformation thereby suppressing short-period ground motion caused by the fault surfaces rubbing against each other. During the recent Chi-Chi, Taiwan, earthquake (M_W=7.6), the observed ground-motion velocity near the northern end of the fault was extremely large (about 3 m/s, the largest ever recorded), but short period acceleration was not particularly strong so that the damage to ordinary structures by shaking was minor. This counter-intuitive observation could be a manifestation of the lubrication effects. However, since this is the only earthquake for which such large slip and slip velocity were instrumentally observed, whether this is indeed a general behavior or not is yet to be seen.

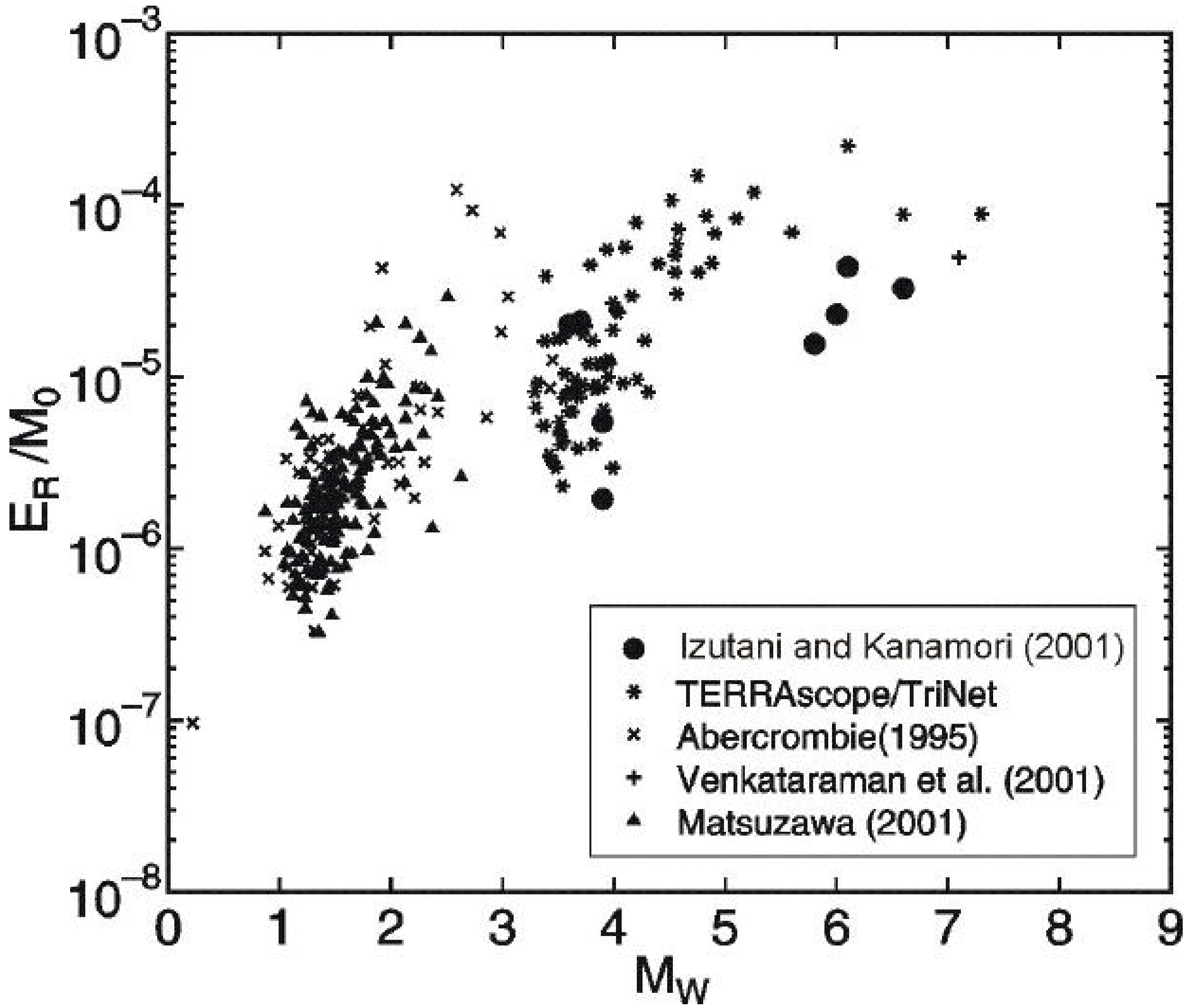

Figure 1

Non-technical Summary

We estimated the amount of energy released in earthquakes using high-quality data. Combining these results with those for small earthquakes, we suggest that small and large earthquakes are very different in rupture dynamics. Large earthquakes occur on well-developed faults, and the fault plane can be lubricated. The fault motion during the recent Chi-Chi earthquake in Taiwan occurred very rapidly (about 3 m/sec), which may be a result of fault lubrication. However, since this is the only earthquake for which such large slip speed was observed, whether this is indeed a general behavior or not is yet to be seen.

Reports

Kanamori, H., and T. H. Heaton, Microscopic and Macroscopic Physics of Earthquakes, in *Geocomplexity and the Physics of Earthquakes, AGU Monograph Series,* edited by D. L. T. John B. Rundle, and W. Klein, American Geophysical Union, Boulder, CO, 2000.

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Kanamori, H., and J. Mori, Microscopic Processes on a Fault Plane and Their Implications for Earthquake Dynamics, in *Seismic modeling of Earth structure,* edited by G. Ekstrom and A. Morelli, Erice, Italy, 2000.

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Data availability

All the data used in the study of Hector Mine earthquake are available from the Data Management Center of IRIS, and the Data Center of the Southern California Earthquake Center.